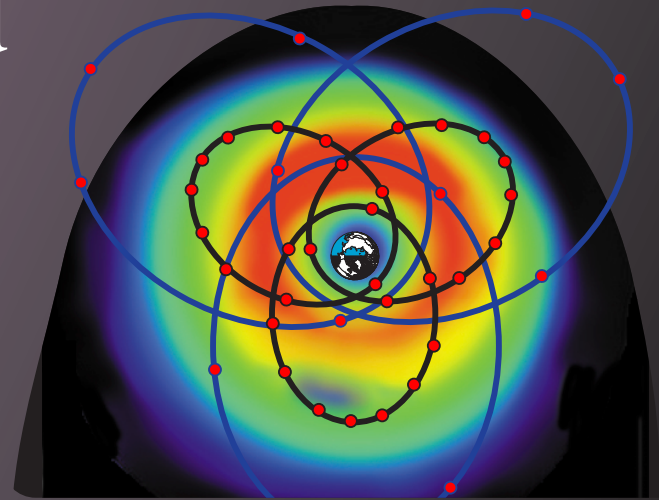


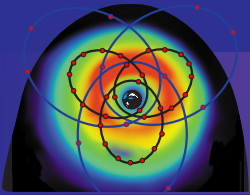
Data Assimilation and Data Synthesis for Magnetospheric Energetic Particles: Current Status and Application to the LWS Radiation Belt Mapper Mission.



Geoffrey D. Reeves

Los Alamos National Laboratory
Space & Atmospheric Sciences

2000 Fall AGU Meeting, San Francisco CA



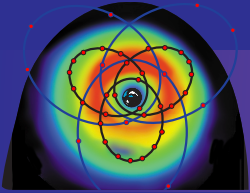
Definitions and Limitations

What is a Data Synthesis/Assimilation Model?

A model that puts together data from a variety of sources, consistent with basic physical principles, in a manner that produces new or enhanced information about a system.

There are many kinds of models that fit this definition

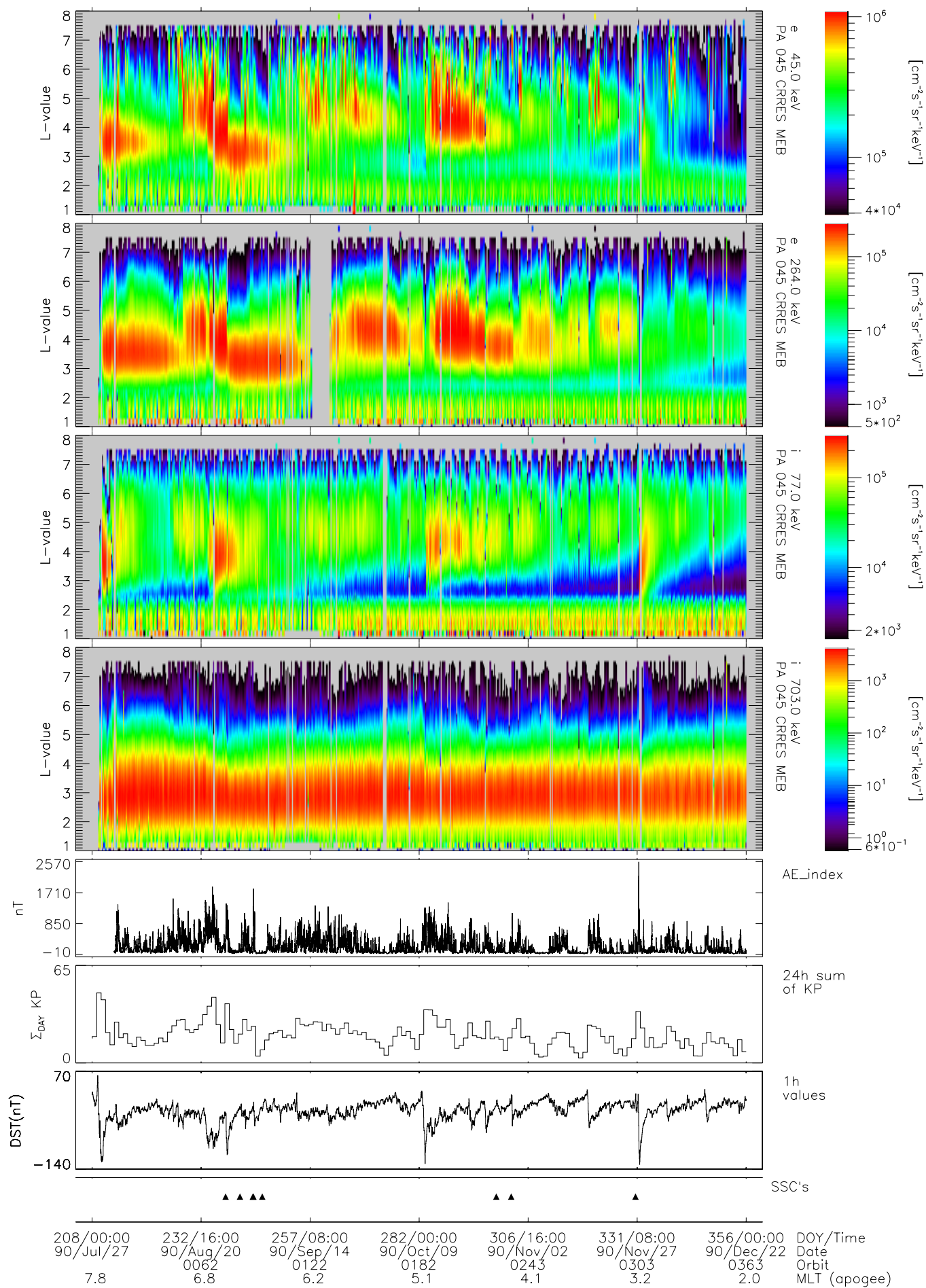
- Global-average models - e.g. AE-8
- Time-dependent models that use data as boundary conditions
e.g. MSFM, Salammbo, ...
- MHD or Particle models with predictor-corrector schemes
- Predictive or statistical models based on multidimensional inputs - e.g. neural network, state space, ...
- Etc....

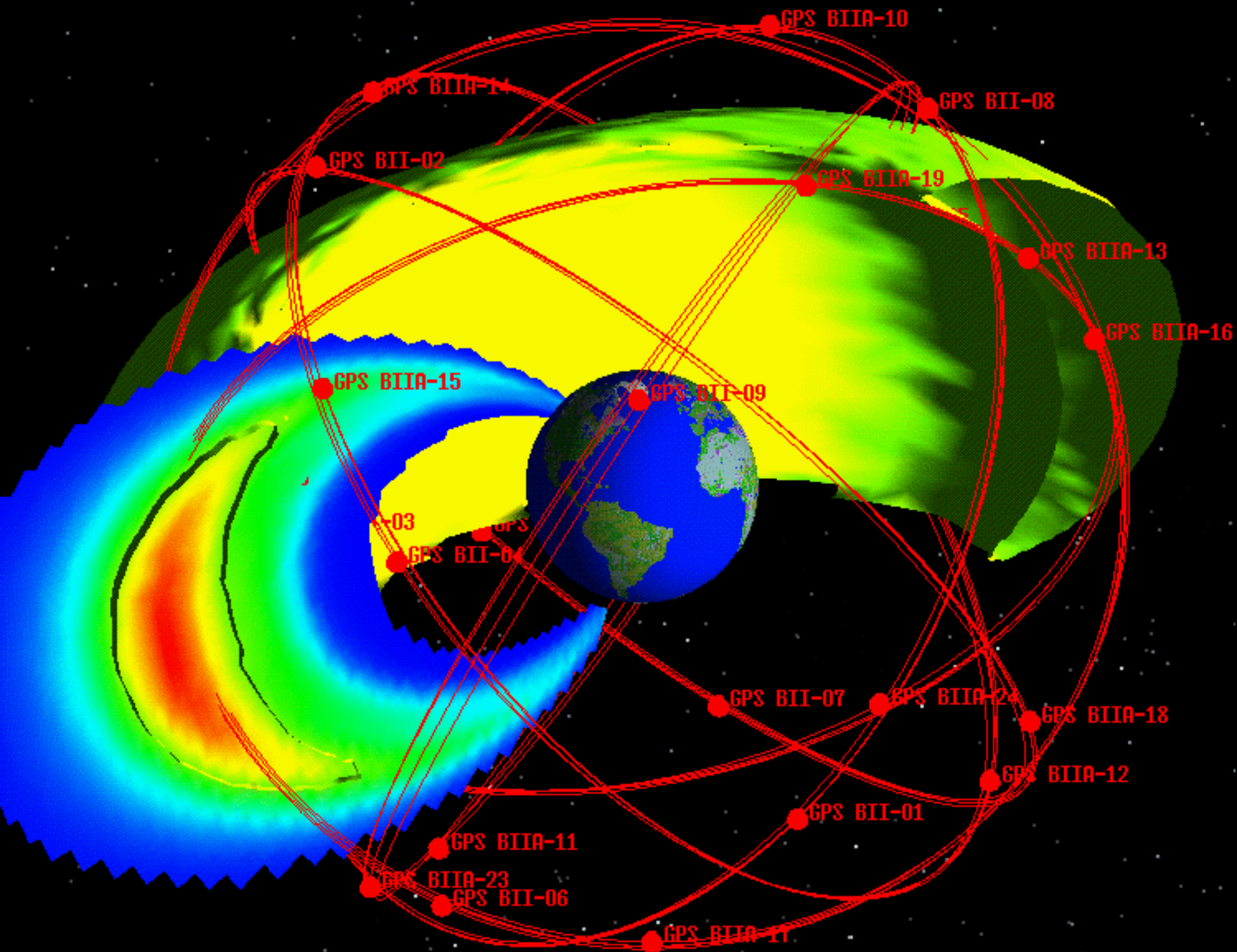


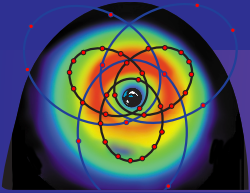
A Partial List of Desired Traits

- Good Spatial Resolution
- Good Temporal Resolution
- Wide range of particle energies - plasmasphere to radiation belts
- Physical particle distribution functions
- Global magnetic and electric field distributions
- Physical time dependence & obedience of Maxwell's equations
- Self-consistent particles and fields in both stationary configurations and time dependence (e.g. particle drifts)
- Accurate representation of magnetospheric particles and fields during average and extreme conditions
- Should be easy, or at least possible to interpret

CRRES OVERVIEW 0.20 L-bins







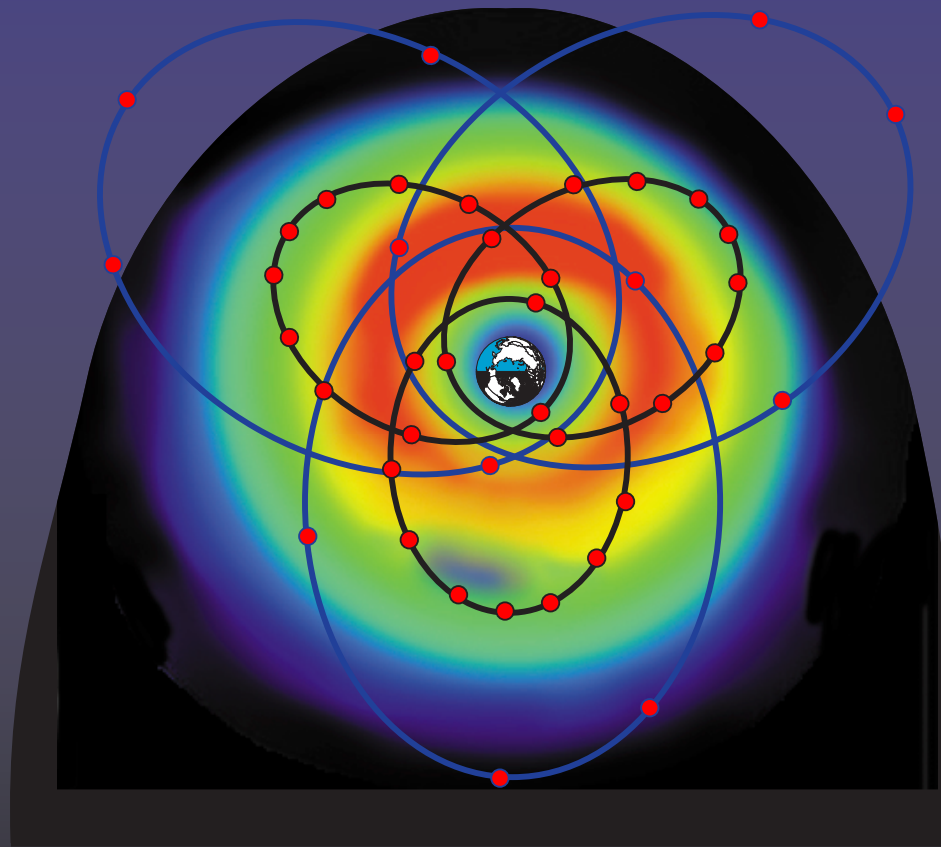
What Will I Talk About?

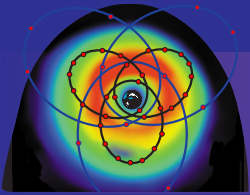
My myopic perspective

- Some of my own experiences with data synthesis
- Mostly will concern energetic particles in the inner magnetosphere
- Will emphasize combining observations from multiple spacecraft
- Hopefully develops creative thinking about the proposed Radiation Belt Mapper mission (RBM)

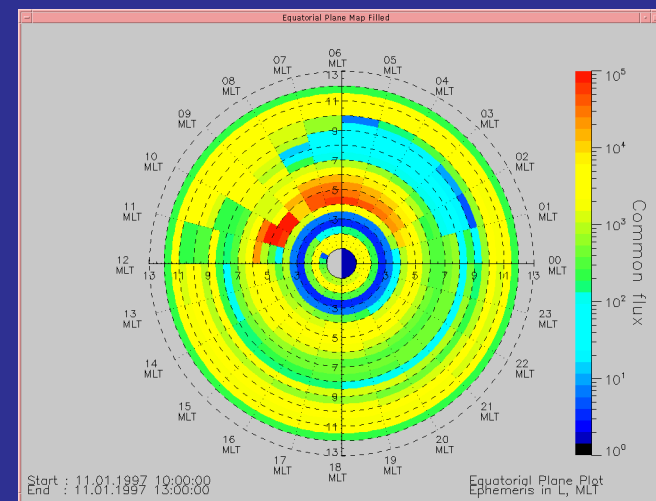
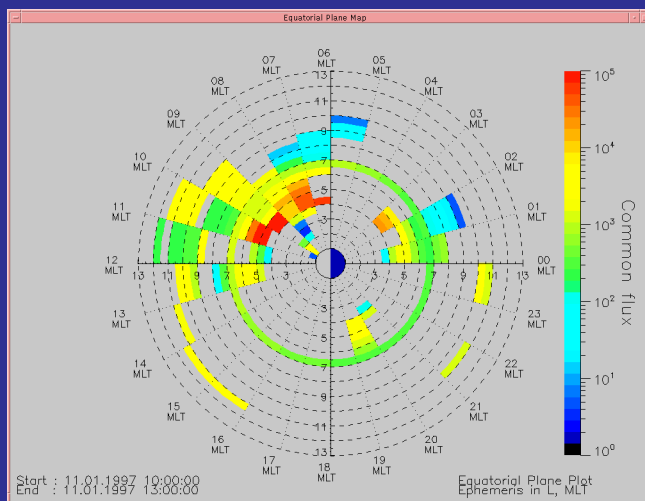
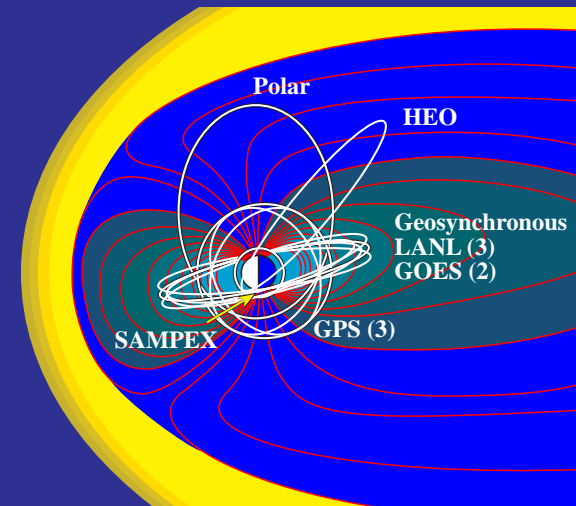
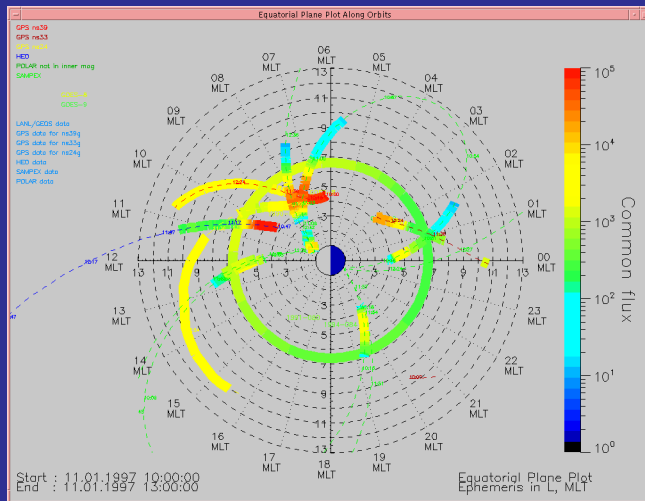
What Is RBM?

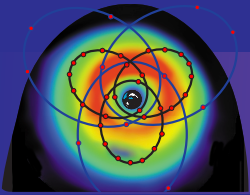
The short answer is “We don’t know...yet.”





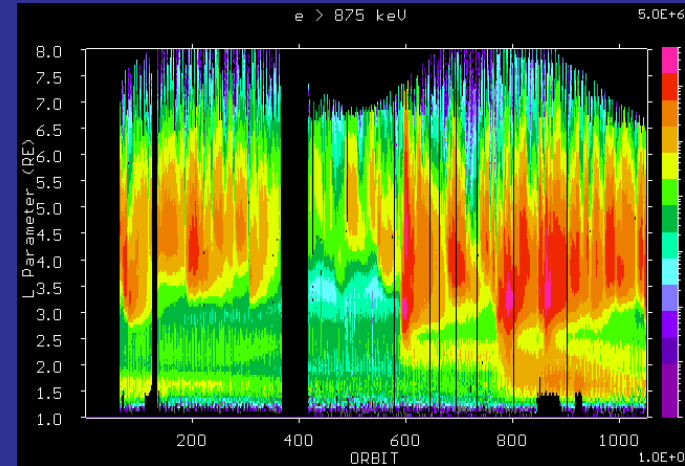
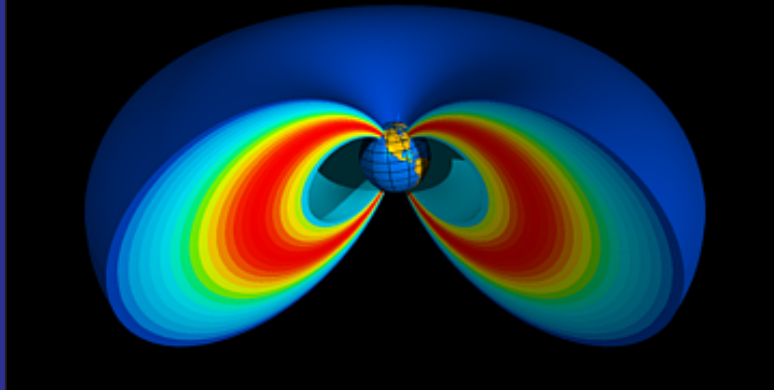
11 Satellite Spatial Coverage



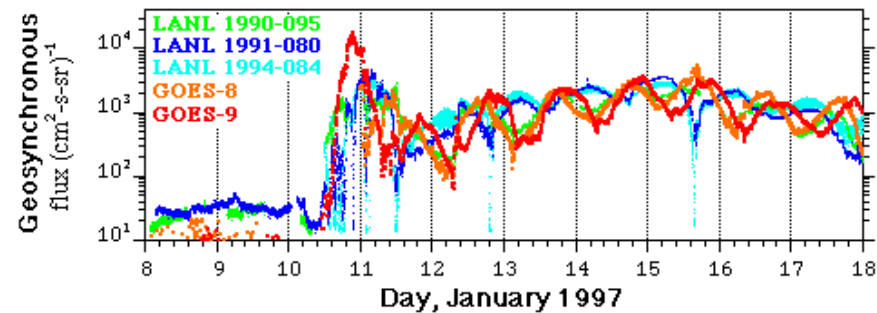
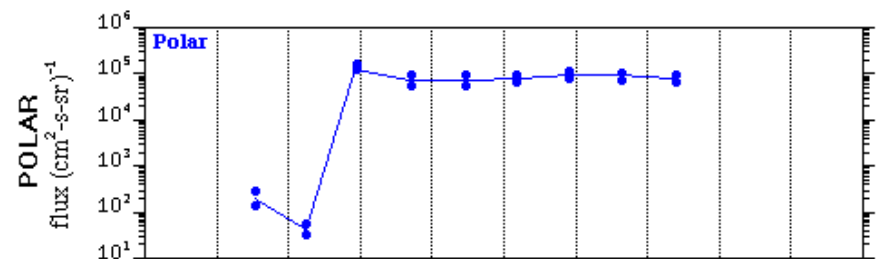
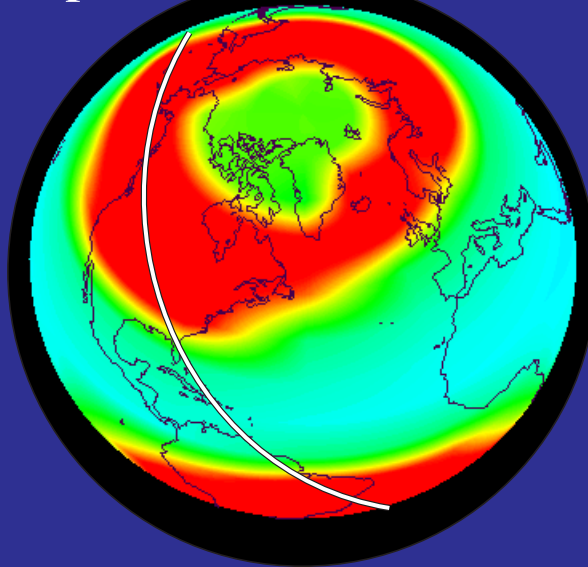


The Spatial/Temporal Tradeoff

Radiation Belts Seen From Polar



Radiation Belts Seen From Space Station Altitudes



Constellation Mission: three

Set 0:

constellation_05_04_06371_35040

Orbital period: 12.3281 hours

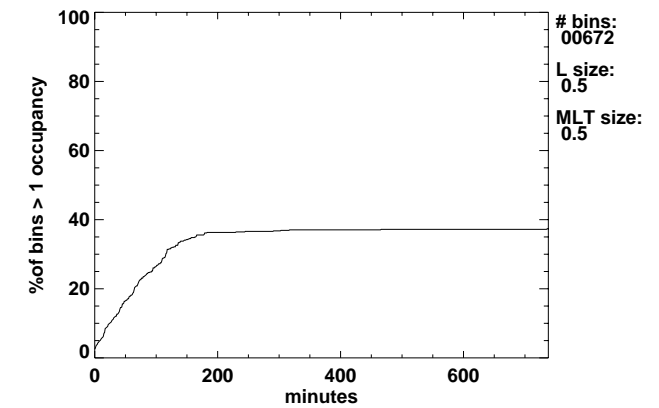
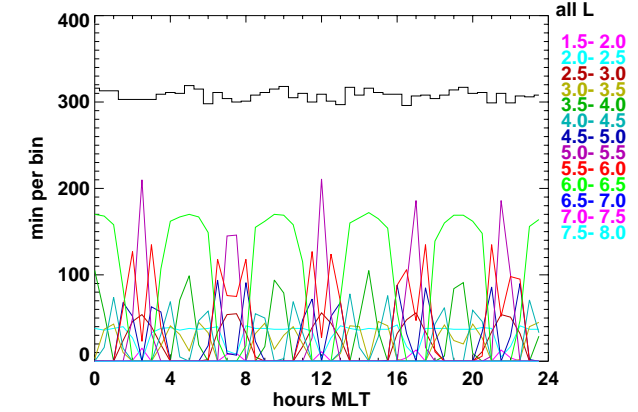
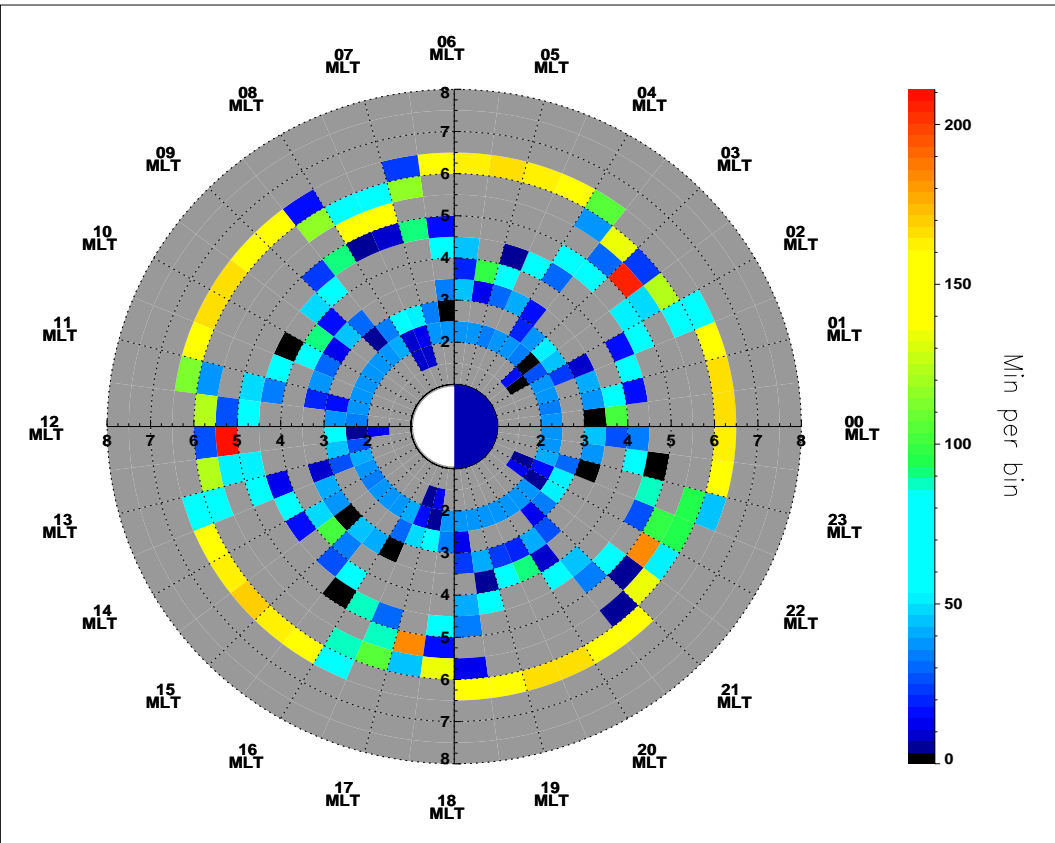
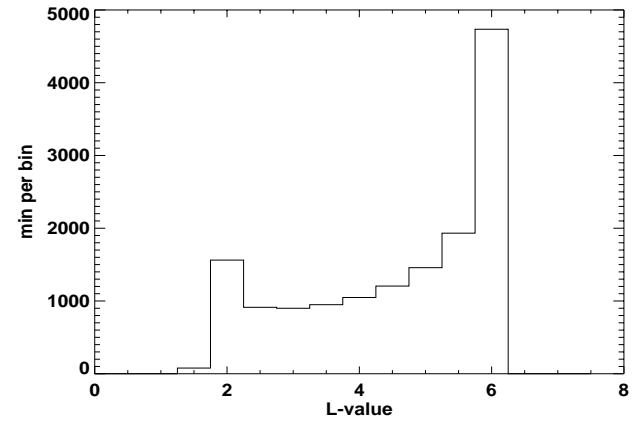
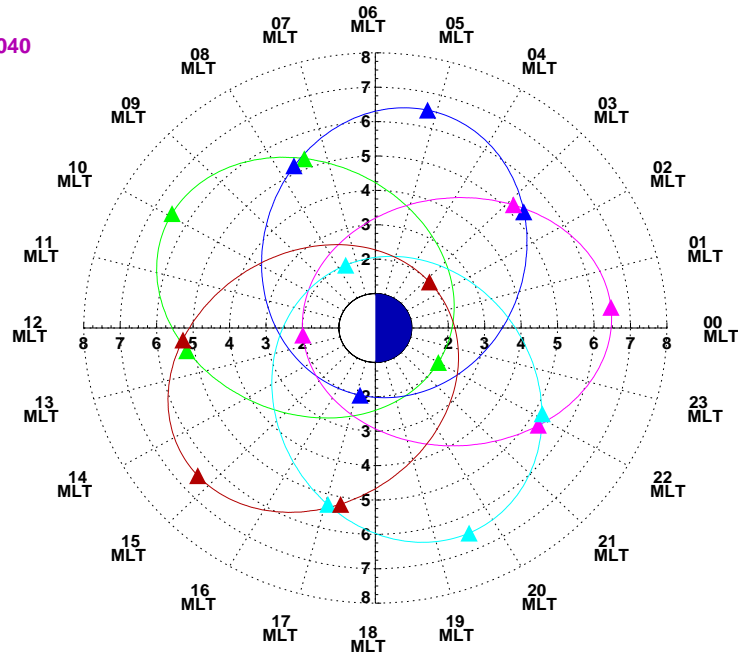
Apogee: 6.50 Re

Perigee: 2.00 Re

Petals: 5

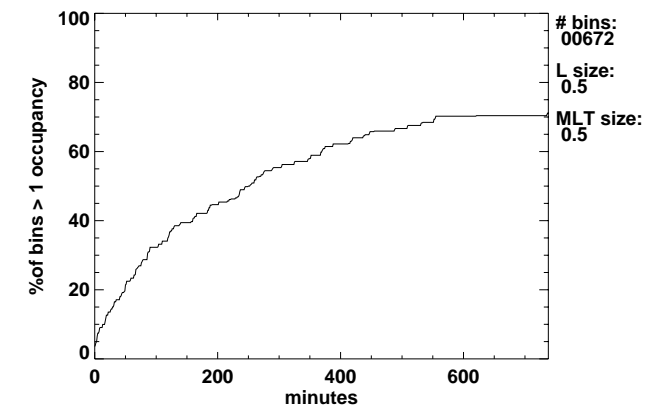
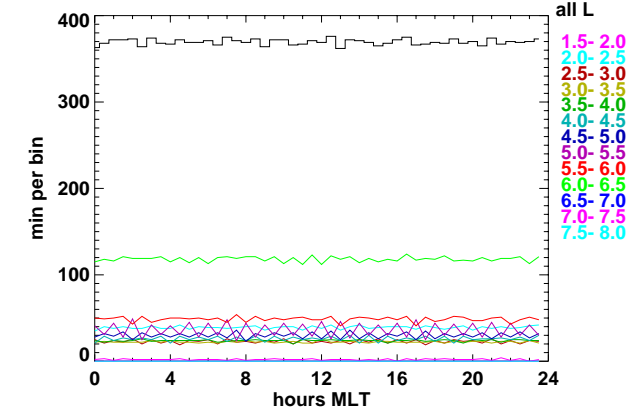
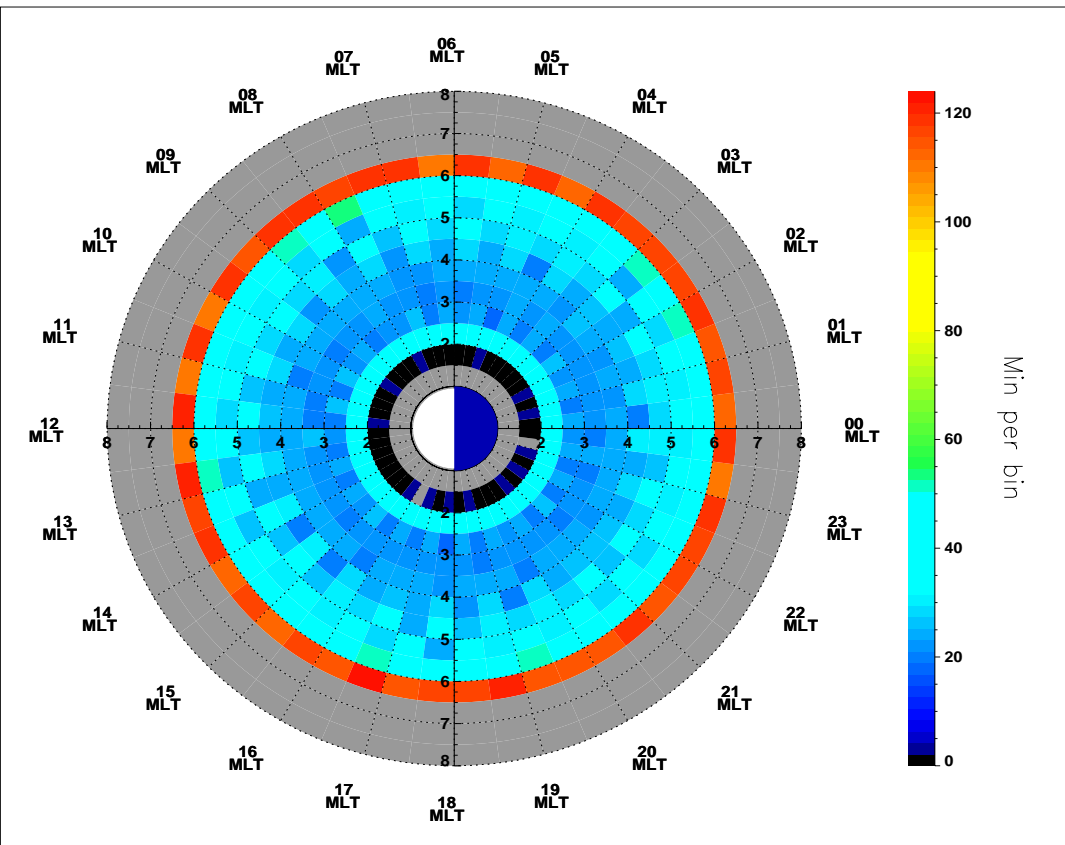
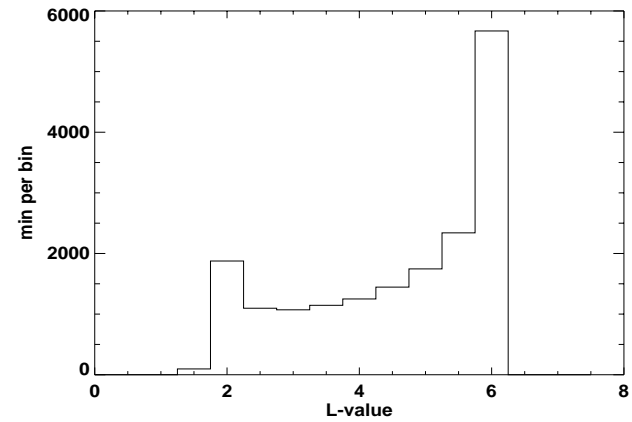
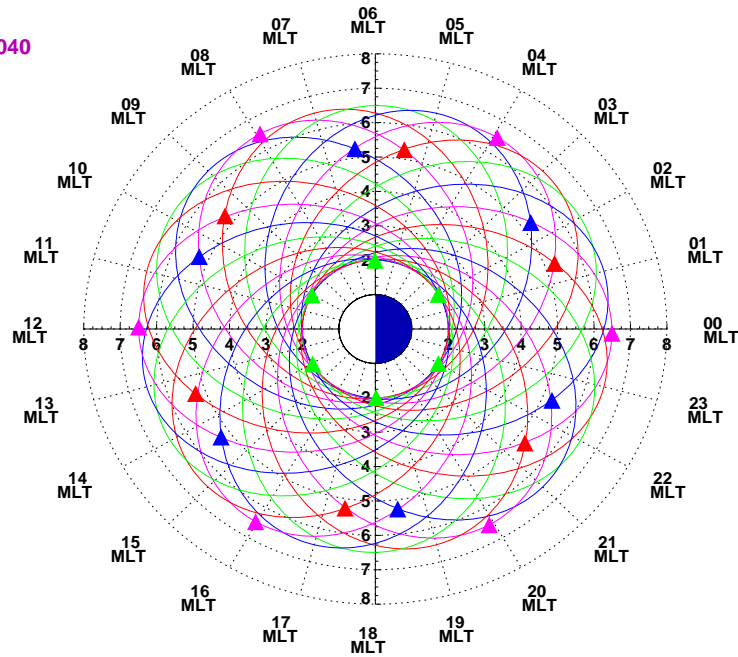
Sats: 4

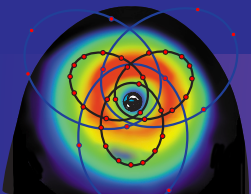
Stagger: 0



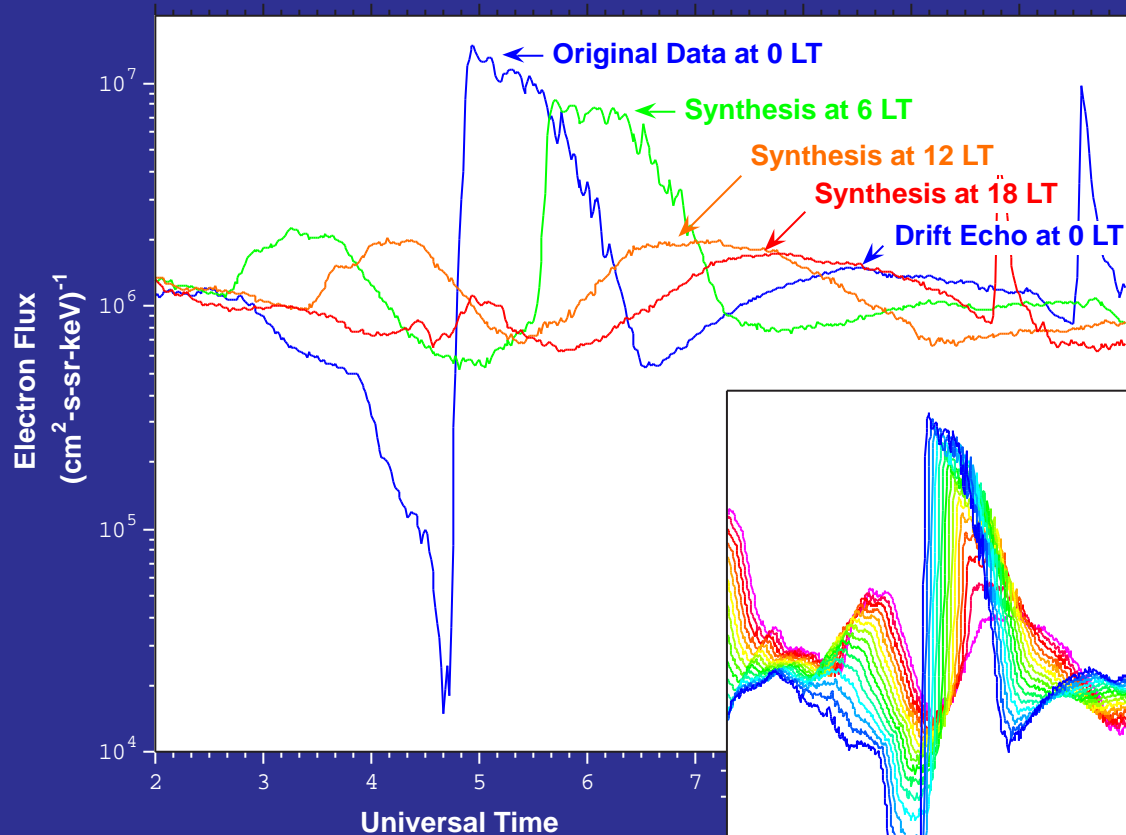
Constellation Mission: one

Set 0:
constellation_24_01_06371_35040
Orbital period: 12.3281 hours
Apogee: 6.50 Re
Perigee: 2.00 Re
Petals: 24
Sats: 1
Stagger: 4

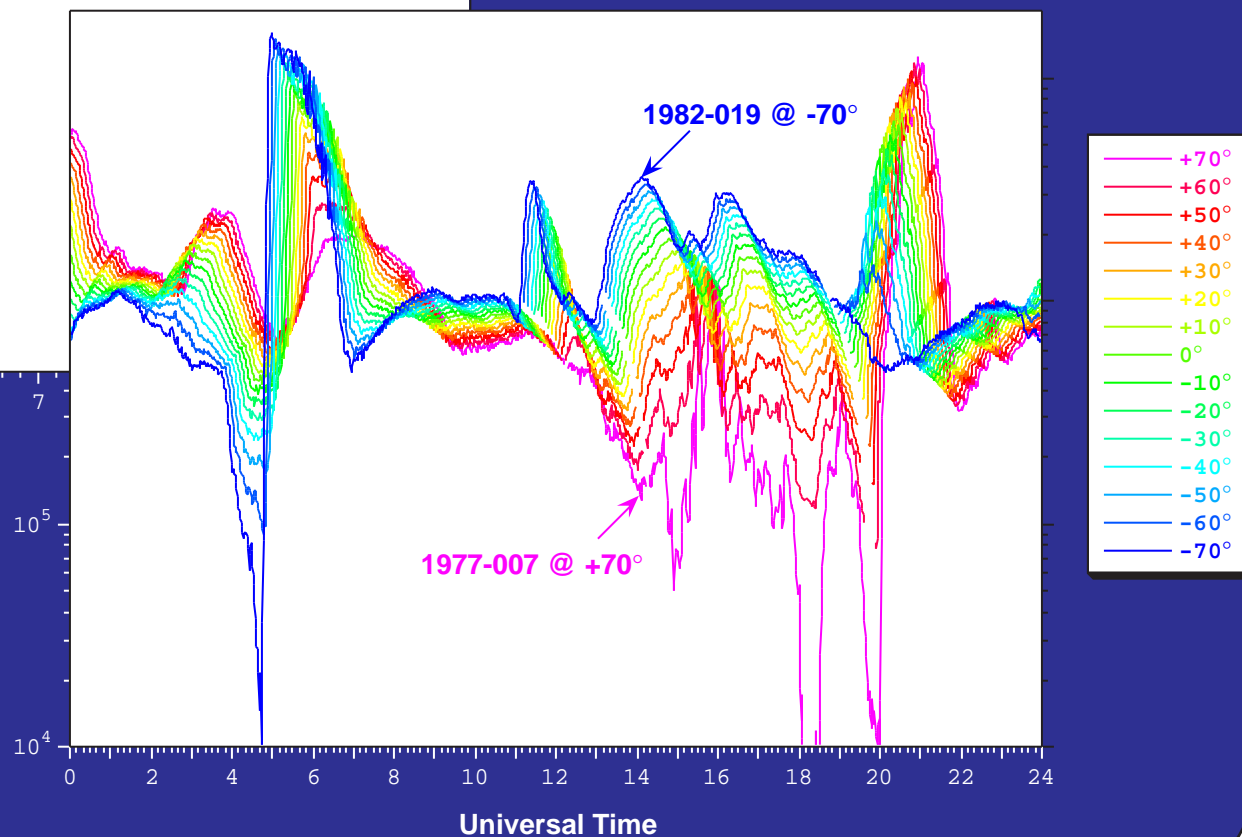


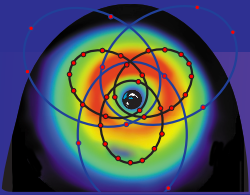


Including Particle Motion



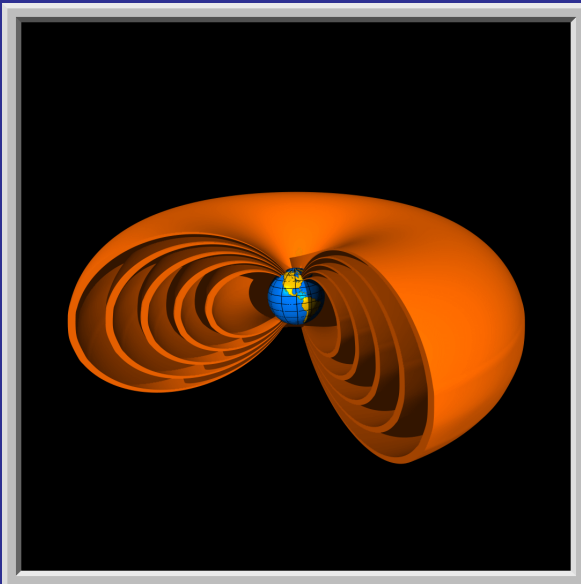
- 3-4 Geosynchronous Satellites
- Linear interpolation based on gradient-curvature drifts
- Fluxes at any UT, LT, or Longitude



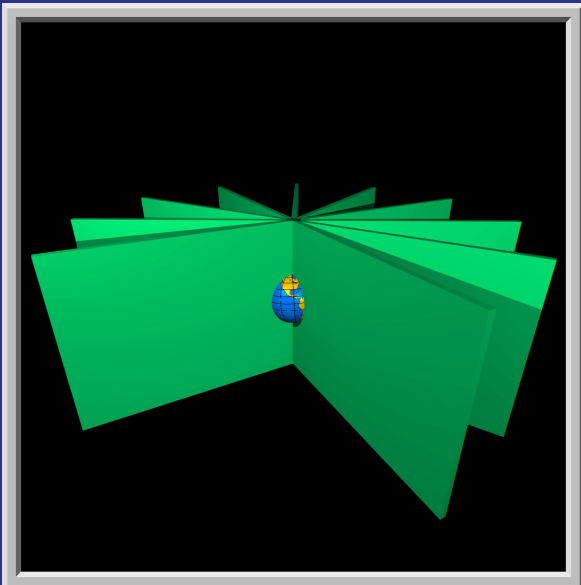


Magnetic Fields & Phase Space

$\alpha = \text{constant}$



$\beta = \text{constant}$



Magnetic field models can be synthesized

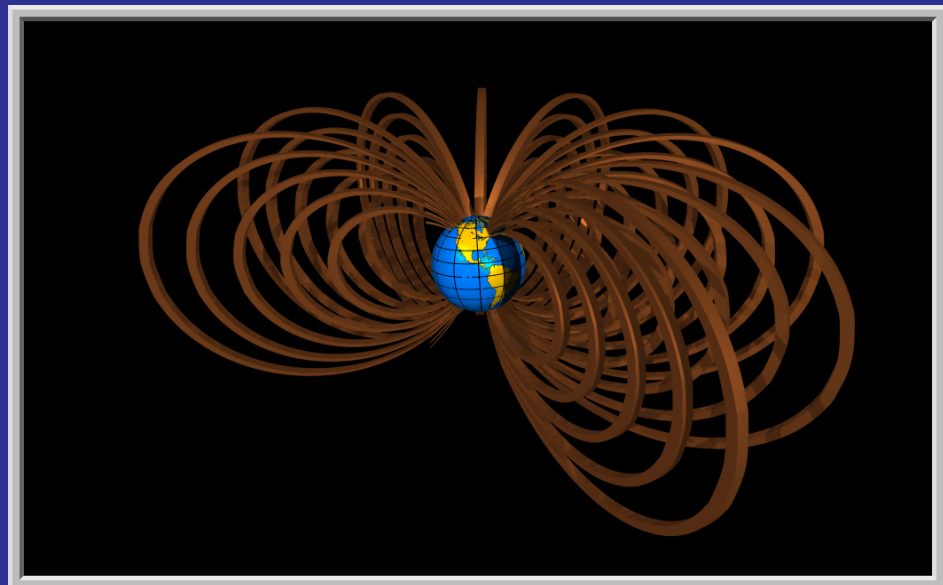
Statistically - e.g. Tsyganenko

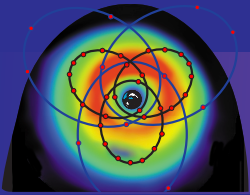
Optimized - Deformable Euler Potentials

Phase Space Densities Can be Calculated

Constant PSD along a drift path adds another powerful constraint on synthesis

$B = \nabla \beta \times \nabla \alpha$



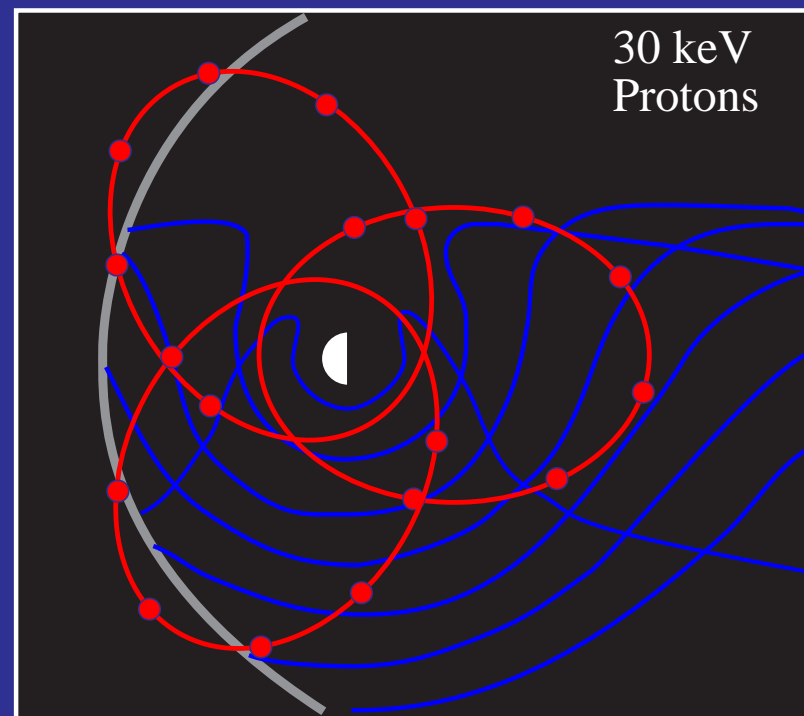
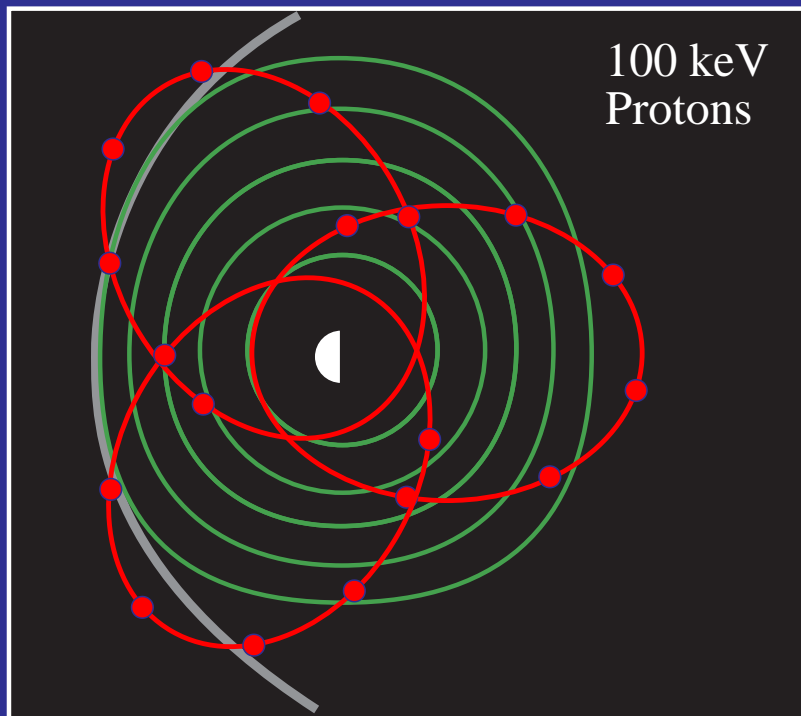


Using Liouville's Theorem

Once the magnetic field is known phase space density trajectories can be calculated directly or iteratively

High-energy particles directly constrain the magnetic field model

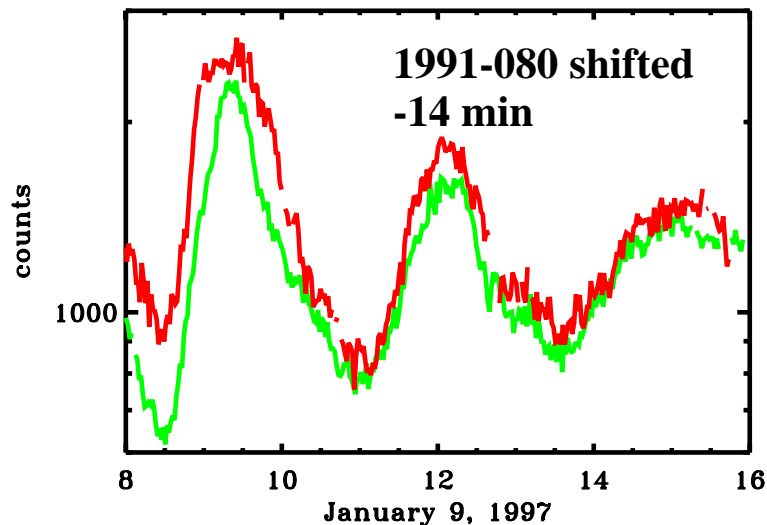
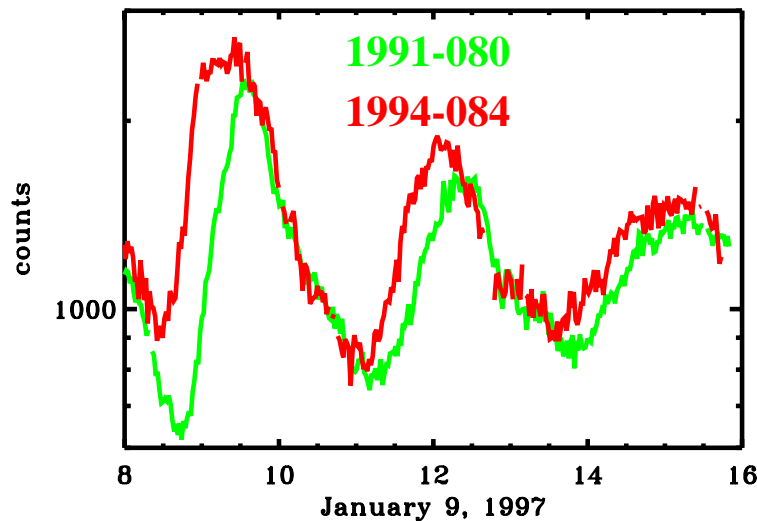
Lower-energy particles likewise constrain the electric field model



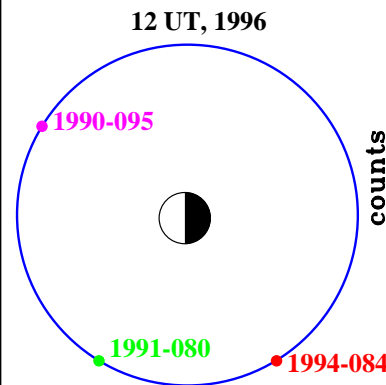
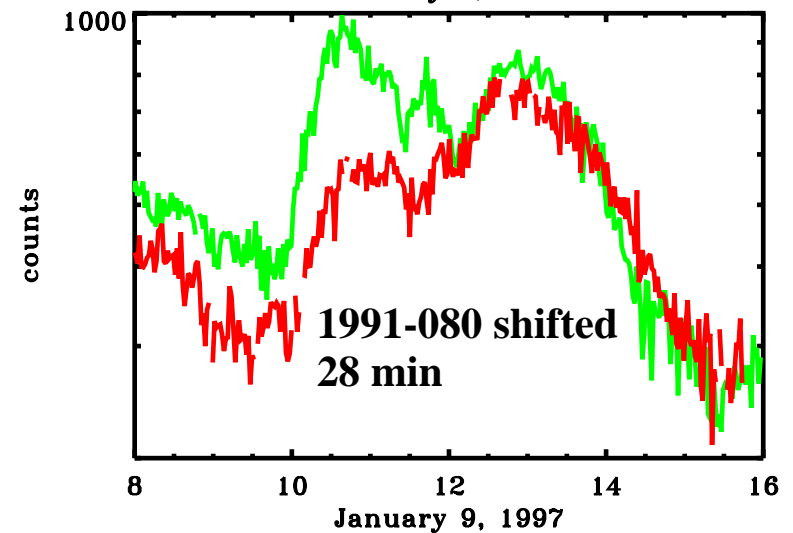
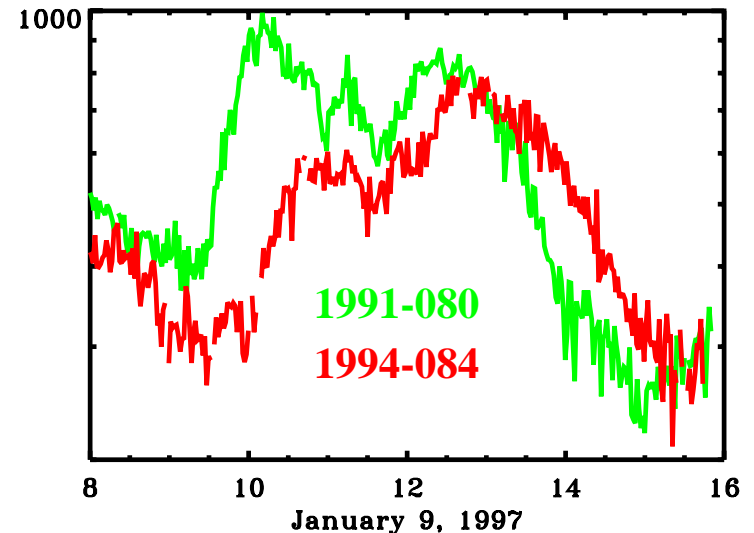
Timing of features

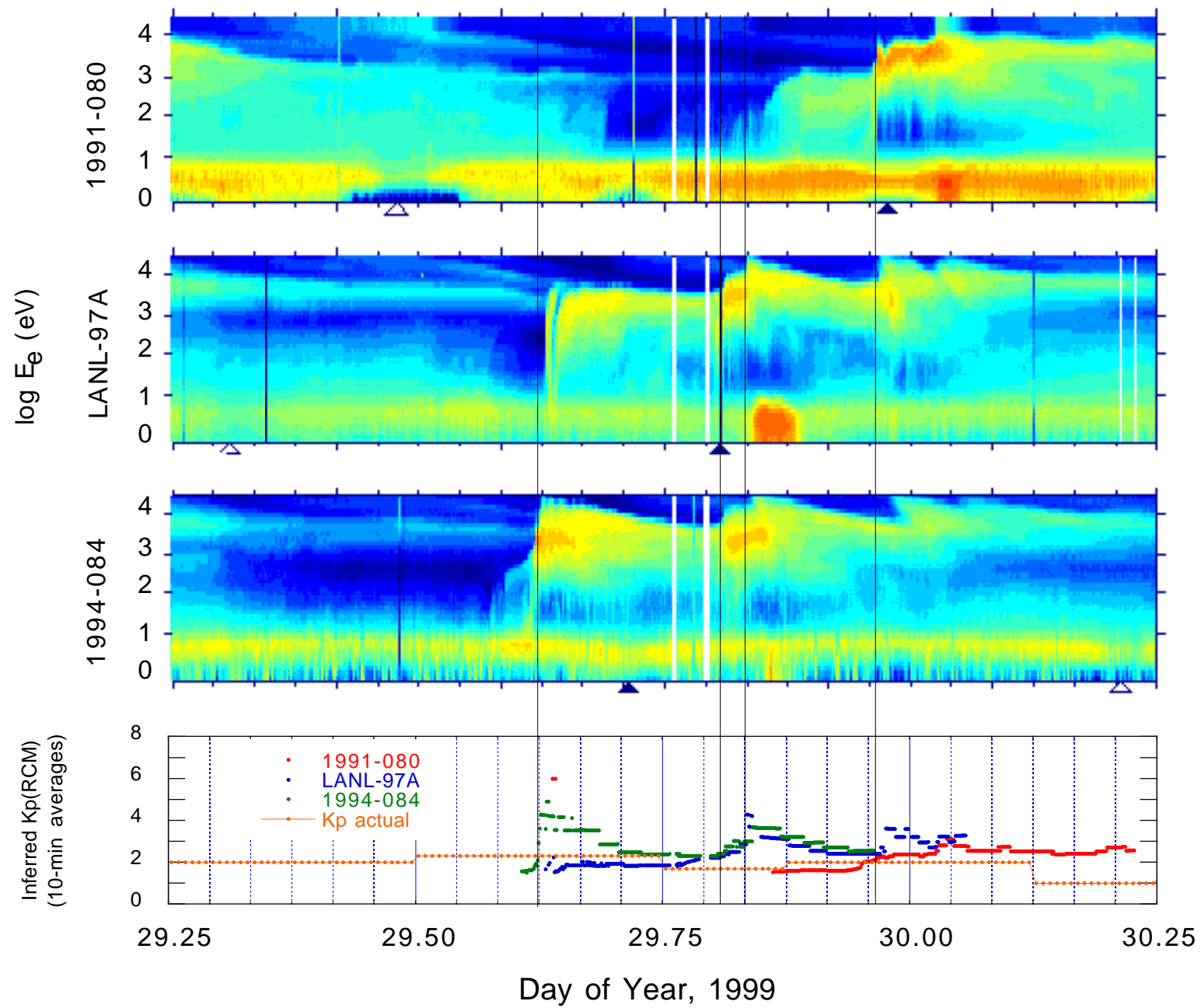
To find the drift time of particles between to satellites we find the time shift between time series of counts, that matches features "best possible."

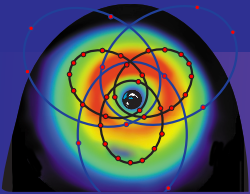
40 keV ions:



25 keV electrons:

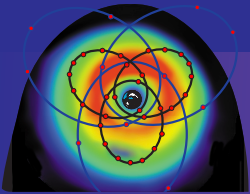






Questions & Challenges

- There are many challenges to achieve a magnetospheric data synthesis model - even with a hypothetical or ideal mission.
- Spatial and Temporal resolution vs. number and configuration of satellites needs to be assessed.
 - * What are the time- and spatial scales of the processes that are of primary interest?
- The number and types of measurements must be balanced against spacecraft size and weight.
- New numerical tools such as deforming a base Tsyganenko model to fit observations using Euler potentials need to be developed.
- Techniques for assimilation of field and particle data into MHD or diffusion simulations need to be developed.



Conclusions

- There is reason for optimism that, given appropriate data, theory, and numerical methods, we will be able to produce a magnetospheric data synthesis model for both basic and applied research
- Self-consistency of particles and fields makes the problem amenable to multidimensional optimization methods
 - * Electric & Magnetic fields, their time variation & Maxwell's Equations
 - * Particle motion in those fields consistent with Liouville's Theorem for all energies
 - * Physical distribution functions in energy and pitch angle
- There are a number of very good starts to these problems and we will learn a lot about the Sun-Earth system in the attempt to solve them.